THE GIANT DINOSAUR: *Rhoetosaurus brownei.*

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With Plates I.–V. and Text-figures.

THE genus *Rhœtosaurus* was established by the writer in March, 1926, for a giant Dinosaur from Jurassic deposits at Durham Downs, Queensland, then only known from a series of caudal vertebræ and a few associated fragments[1]. Through the courtesy of Mr. Arthur J. Browne, whose name was associated specifically with this remarkable fossil, I was able to pay a short visit to the actual site of the discovery in May, 1926. With Mr. Browne's assistance very important additional material was found, which adds greatly to our knowledge of this huge Sauropod. The remains were partly exposed but mostly buried under soil on a slope near the bank of a small gully, which runs into Eurombah Creek. At the time of our visit the much abraded lateral surfaces of about a dozen vertebræ could be distinguished on the surface. Some of these were practically in juxtaposition. These vertebræ and the associated matrix have apparently been weathered out of the original formation. As the result of spade and mattock work many additional fragments were unearthed, these being irregularly scattered in the soil over an area of several yards. Fully a ton of material, apart from fragments of sandstone, was recovered in this way within two days. Should other fragments of the same skeleton be present, it seems probable that these may be uncovered in favourable circumstances after heavy storms.

The specimens were then set on one side for subsequent transit. As the site was about four miles from the homestead, the fossils had to be conveyed for some distance over very rough country and across several gullies to Durham Downs. They were then sent by motor truck some forty miles to Roma, and subsequently railed to Brisbane. Mr. Browne's valuable assistance in arranging for the conveyance of this heavy material is greatly appreciated.

Horizon.—In my previous paper this was designated as "Walloon Series, Jurassic, Freshwater"; in this connection references were given to papers by H. I. Jensen, B. Dunstan, and A. B. Walkom, and the details need not be repeated here.

Material.—The additional specimens comprise about twenty vertebræ, ranging from small sections of centra or arches to fairly complete units. Some

[1] Longman, Mem. Queensland Museum, VIII., part 3, 1926, pp. 183-194, Plates XXIX.–XXXIII.

of the more complete specimens had sustained transverse fractures, but the component parts were lying in close association. When uncovered and lifted from the soil, one of the larger vertebræ, which appeared to be fairly solid, fell into scores of pieces. The vertebræ discovered include six additional caudals, the coalesced but very incomplete remains of four sacrals, representatives of at least seven dorsals, and one cervical. Short sections of a massive femur were found involved in thick matrix. Scores of fragments, many of which belonged to the pelvic girdle, were also collected. Some of the specimens have not yet been sufficiently freed from matrix to be available for description. Many of the smaller fragments, however, consist of abraded bone with but little matrix adhering.

Matrix.—As in the previously described specimens, the matrix is of two kinds. The major portion consists of masses of oxidised concretionary clay ironstone, which can be readily chipped away from the more massive elements. Underlying this on many of the specimens is a closely-investing, very fine-grained, calcareous sandstone. This proves most difficult to remove, and, up to the present, it has been found almost impossible to clear sections of this natural cement from the more friable contours of the actual fossil, even when these have been reinforced by shellac solution.

Dorsal Vertebræ.—Although the specimens representing the dorsal series are in a tantalising condition, there is definite evidence that the rib-bearing vertebræ of *Rhætosaurus*, whilst possessing special features, exhibit the remarkable characters typical of several other giant Sauropoda. There are lateral cavities or pleurocœlia in the massive centra, which are opisthocœlous. The neural arches are very complex, with bracing laminæ, small, horizontal, elevated zygapophysial articulations, and extensive intra-mural cavities. The main articulating medium is composed of the extensive hyposphene-hypantrum elements.

For purposes of convenience, the five more complete specimens of dorsal vertebræ have been lettered A to E. As will be seen from further descriptions, vertebra A appears to be one of the anterior units, whilst B, C, D, and E are from a more posterior region. These massive vertebræ attain a vertical height of 65 cm. in the portion preserved. The average length of the centra is 18 cm., and the maximum breadth across the expanded articulating surface is approximately 24 cm.

Although incomplete, the vertical extent of the neural arches above the floor of the neural canal, even apart from the spine elevations, exceeds the maximum vertical extent of the centrum.

It is obvious that the vertebræ preserved exhibit the great variability recorded by several authorities for the Sauropoda. There is also evidence of marked asymmetry in the same specimen, even when all the exigencies of distortion during fossilization are taken into consideration.

Fig. 1.

Fig. 2.

Fig. 1.—Anterior Dorsal Vertebra of *Rhætosaurus brownei*, posterior view.
Fig. 2.—Anterior Dorsal Vertebra of *Rhætosaurus brownei*, lateral view.
(Two-ninths natural size.)

Face page 2.

Specimen A represents a fairly-complete dorsal (Plate I., figs. 1 and 2). The centrum is much distorted and is obliquely compressed laterally. As both intervertebral surfaces are preserved the opisthocœlous character of this dorsal is well shown. This unit is of special interest because it illustrates the position of the parapophysis for the head of the rib. The parapophysis is situated in the centre of the lateral aspect of the neural arch. It arises from the infradiapophysial lamina, and forms a prominent buttress, projecting about 50 mm. from the plane of the arch. This corresponds somewhat with the position of the parapophyses in *Camarasaurus supremus* (Osborn and Mook, Plate LXXII., No. 3)[2], but in our specimen the process is more centrally situated. Incidentally, it may be noted that this marked variation in the position of capitular rib facets on the anterior vertebræ may be seen in a skeleton of a modern crocodile.

The total height of vertebra A, as preserved, is 57 cm. The length of the centrum is 22 cm., and it has been compressed laterally to about 11 cm. Had this vertebra not been collected in the same place and at the same time as the other remains, it might well have been considered as representing a distinct species. The pleurocœle, which has not been fully outlined from the matrix, is indistinct on the Plate.

Specimen B consists of a complete although fractured centrum and the associated half of a second. The neural arches are almost entirely missing. Specimens C, D, and E represent contiguous vertebræ, the last two being fairly complete (Plate II.). The following descriptions of the chief features are mainly based on the characteristics of these two vertebræ.

The Centra.—The opisthocœlous character of the massive centra is distinctly marked, both "balls" and sockets being fairly well shown. There is a median constriction accompanied by expanded articular surfaces. The intervertebral articulations appear to have been vertical and the specimens preserved do not suggest any very marked curve in the column in the dorsal region. Each vertebra has a large oval pleurocœle extending for about two-thirds the antero-posterior diameter of the centrum, but these are not clearly shown on the Plates. The lower margin of this pleurocœle is situated somewhat above the middle line of the centrum in D and E. The opening is not so elongated as that in the dorsals of *Ornithopsis*.

On the ventral surface of Vertebra B there is a strong blunt keel running between the expanded articulating surfaces. There is no evidence of a similar keel on the other specimens.

Neural Canal.—There are extensive intra-mural cavities, now infilled chiefly with clay-ironstone, near the region of the neural canal, which is

[2] Osborn & Mook, Mem. Amer. Mus. Nat. Hist., Vol. III., pt. 3, 1921.

elongate-oval or sub-triangular in section. Owing to distortion there is much variability, but the canal averages about 55 mm. in height, whilst the base is about 45 mm. in breadth.

Neural Arch.—In the region of the neural spines all of the specimens are very distorted, fractured and abraded, and the difficulties of development and description seemed at first almost insuperable. In specimens C and D the extensive diapophysial elements have been crushed back towards the median line. When exposing the laminar structures from the over-lying and under-lying material, it was found that some of the contours of the actual bones had been abraded before being covered with the present matrix. The original contours are thus in places very obscure. To add to the difficulties, some of the laminæ are extremely thin, and could only be developed after repeated soakings in adhesive solutions.

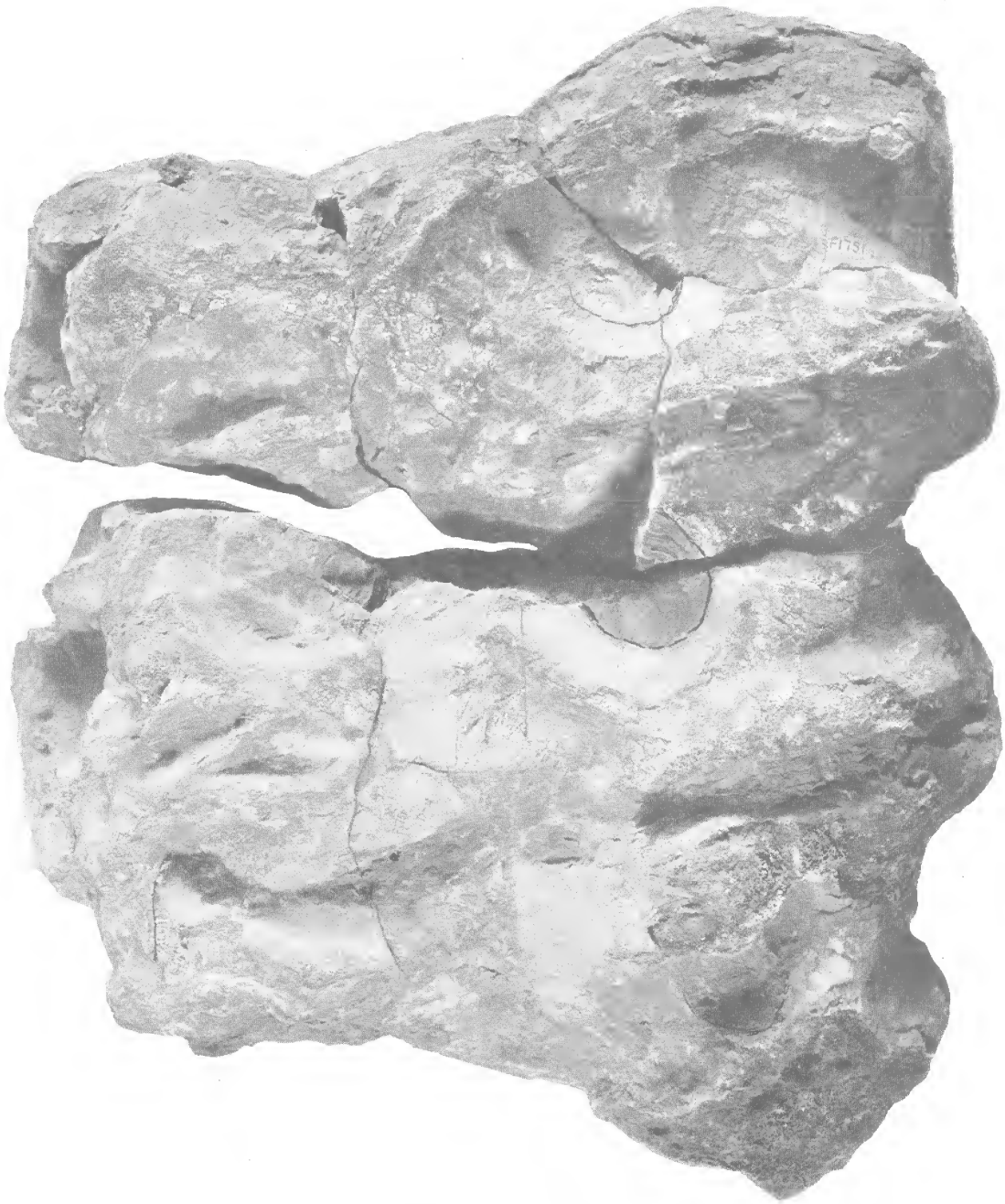
Although no specimen illustrates the complete contours of the spine, it does not appear to have had great vertical extension. On specimens D and E there are undoubtedly paired metapophyses, but these are not greatly elevated and are distinct from the true spine, being part of the diapophysial architecture. There is no evidence for a bifurcated spine in the dorsal region.

The lateral surfaces of the neural arches are mainly composed of a complex of laminæ, which brace the zygapophyses and rib facets, strengthening the thin walls, behind which are extensive cavities. Of these laminæ the infradiapophysial is more prominent than the pre- and post-zygapophysial structures. There may be an oblique branch from the infradiapophysial lamina, and in one specimen there is a supplementary branch uniting it to the horizontal lamina. The associated cavities are relatively shallow, much more so than in *Camarasaurus*.

It is impossible accurately to describe the characteristics of the diapophyses of the posterior dorsals. Evidently they were situated above or on a level with the zygapophysial articulations, and, judging from the position of fractured surfaces, they extended outwards and upwards.

The Zygapophyses.—These are small articular surfaces occupying an elevated position. When viewed from both the lateral and intervertebral planes these surfaces are fairly horizontal. At the lateral borders of the zygapophyses the breadth of the neural arch is actually greater than the maximum breadth of the centrum. Each facet is thus widely separated from the corresponding structure on the other side.

Hyposphene-hypantrum.—The actual hyposphenal elements are extensive when viewed in transverse section; the breadth may be equal to about two-thirds of the entire neural arch. Judging from the condition of these elements as seen in exposed fractures, the contiguous vertebræ of parts of the dorsal series were almost rigidly articulated. The articular complex, when exposed in this way, shows the shorn elements of the hyposphene still rigidly adhering



Conjoined Dorsal Vertebræ of *Rhætosaurus brownei*. (Two-ninths natural size.)

Face page 4.

to the hypantral or lateral surfaces. The wedge could not be withdrawn from the antrum, but sustained transverse fracture when separation was enforced during fossilization.

The area is obscure, but the median portion of the upper part of the hyposphene is broad and much curved on its superior border, when viewed from the intervertebral plane. This structure is concave, when viewed from the lateral plane as it is produced downwards between the postzygapophyses (specimen D).

Incomplete sections of the neural arch, which have been partly cleared from matrix, bring to mind the difficulties that confronted Hulke when he first described a fragment from the Wealden as *Eucamerotus*, which he subsequently associated with *Ornithopsis*[3], but the upper median portion of the hyposphene is very different from that of *Ornithopsis*[4], as figured by Hulke (1880).

From close examination of the five dorsal elements, it is very clear that the hyposphene with its associated plates forms an articular complex which projects greatly over the centrum of the contiguous vertebra. This projection, however, is confined to the upper portion of the neural arches.

This overlapping of the hyposphenal complex appears to have been far more marked in the posterior vertebræ than in the anterior one denoted as A. From this evidence it seems certain that the posterior dorsal region of *Rhœtosaurus* was much more rigidly articulated than the anterior portion. In other Dinosaurs there is evidence for a flexibility in the fore part of the body, combined with relative rigidity in the hind part and tail. This has been graphically demonstrated by the fine material so fully described by Osborn and Mook in the monograph on *Camarasaurus*, where there "were two distinct presacral regions, one mobile and the other fixed. The mobile region included the head, the cervicals and the first two dorsals, whilst the fixed region included the remainder of the dorsals."

E. D. Cope, following H. G. Seeley and J. W. Hulke, considered that the hollow vertebræ were "probably penetrated in life by branches from the lungs" and that these served as "floats" and the solid limb bones and tail vertebræ as "anchors" as they walked in the water[5].

As the number of dorsal vertebræ varies from 10 in *Diplodocus* and *Apatosaurus* to 12 in *Camarasaurus* and 14 in *Haplocanthosaurus*, the five units noted above probably represent about half of the full dorsal series for *Rhœtosausus*.

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[3] J. W. Hulke, Quart. Journ. Geol. Soc., 1870, XXVI., Plate XXII.

[4] J. W. Hulke, Quart. Journ. Geol. Soc., 1880, XXXVI., Pl. IV.

[5] E. D. Cope, Syll. Lect. Geol. and Pal., Philadelphia, 1891, p. 43.

Ribs.—No significant remains of ribs are present, but a fragment, taken from the lateral matrix of the dorsal vertebra A, illustrated a characteristic enlargement of the rib for capitular and tubercular facets; the latter is very incomplete.

Sacral Vertebræ.—There are remains of four sacral vertebræ found ankylosed in one piece, which was heavily involved in matrix (Plate III., fig. 1). The first and fourth elements in this piece consist of very incomplete centra, and the anterior may represent a dorso-sacral, or, alternatively, the posterior may be a caudo-sacral. The centra of the two middle vertebræ are well preserved, but the neural arches are far from complete. A striking feature of these vertebræ is the transverse breadth, which is greater than the length. In the best-preserved centrum the breadth at the confluence of the ankylosed vertebræ is 23 cm. The length of the two is surprisingly irregular, the anterior being 16 cm. and the contiguous one 21 cm.

On the lower surface these vertebræ are slightly concave, when viewed laterally, but somewhat less so than in the characteristic dorsals. This lower surface is very massive; the body is much flattened transversely in this area and the breadth is a well-marked feature. The infero-lateral areas are, however, much constricted below the diapophyses.

Although the diapophyses connecting these vertebræ with the sacricostal yoke are not preserved, valuable information regarding their shape and extent is yielded by exposed areas of fracture, which are angular or ⊥ shaped. In the larger vertebra this area of fracture occupies the greater part of the lateral area of the centrum. The lower part is a broad band 150 mm. long and 50 mm. deep; superiorly this band is produced into a median buttress, which gradually becomes thinner until it merges into the region of the neural spines. Here it becomes quite laminar. In the more anterior vertebra the area of fracture denotes a far less massive architecture for the union with the ilium. On either side of these areas of fracture, the centra are very concave, and the periphery of the ankylosed intervertebral surfaces stands well out.

The contours of the neural arches are very confused, owing to the incompleteness of the portions preserved and fractures and compressions. The area of the neural canal, which was evidently extensive, has been much distorted.

At their origin near the centra the neural arches appear to have been ankylosed with their fellows, but the distal elements of the two central vertebræ appear to have been distinct. The neural arches are partly composed of oblique laminar buttresses, which appear to overlie portions of corresponding buttresses of contiguous vertebræ. Although the region is decidedly complex, the ossification is evidently more solid than in the dorsal series. This solidity was obviously required to strengthen the architecture of the massive pelvic girdles. The elongated laminar processes resemble in some respects those figured by Osborn and Mook in *Camarasaurus*.

Fig. 1.—Incomplete Sacrum of *Rhætosaurus brownei*.

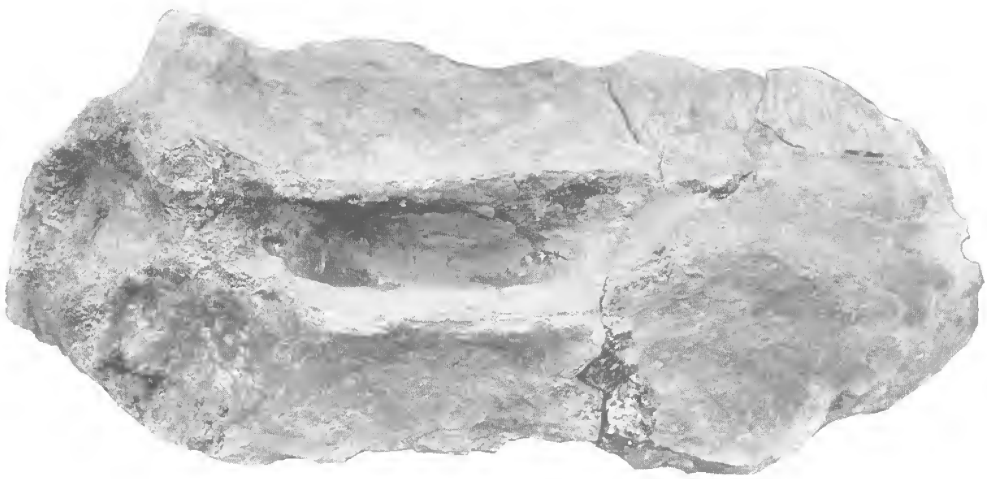


Fig. 2.—Cervical vertebra of *Rhætosaurus brownei*, superior view.
(Five-eighteenths natural size.)

Face page 6.

The portion of these sacral vertebræ preserved has a total height of 40 cm. Owing to their increase in breadth the centra in this region are almost circular in section, but they are relatively smaller than the posterior dorsals and the anterior caudals. There is no evidence of pleurocœlia.

Caudal Vertebræ.—Several additional fragmentary caudal vertebræ are now added to the twenty-two in the original description. The most significant of these are four which can be placed in serial alignment on the pelvic side of the consecutive series illustrated last year. Although "at least one additional caudal" was anticipated in my first paper, the presence of four still larger caudals is surprising. These specimens are very much abraded and do not present special characteristics apart from those previously dealt with in detail. The fourth attains a maximum height of 53 cm., but the spine is incomplete.

Pelvic Girdle.—Ilium: There are several massive fragments that represent disrupted and much abraded ilia, but they are not in a condition to admit of any satisfactory reconstruction. Fragments of the anterior crest and what is probably the pubic peduncle illustrate the immense size of the ilia, but do not lend themselves to descriptions that would be of value. An abraded portion of the iliac periphery of the acetabulum is largely embedded in matrix. It is evident that this fossil was subjected to intense strains to bring about such disruption.

Ischia.—No significant additions have been made to the fragments noted in my first paper, but it is obvious that the shaft of the ischium was relatively long and slender. The transverse sections grade from oval to sub-triangular.

Pubis.—Remains of both left and right pubes have been put together from over a dozen detached fragments and are illustrated in Plate IV., figs. 1 and 2. These pubes are of the massive elongated type of the Camarasaurian Dinosaurs, *sensu latiore*, but they do not very closely correspond with the figures of either *Camarasaurus*, *Brontosaurus*, *Ornithopsis*, *Haplocanthosaurus*, or with *Diplodocus*.

Since the right pubis was photographed, the greater part of the distal end has been located and freed from matrix. It corresponds in size and contours with the distal end of the left pubis. It is estimated that these pubes attained a length of about 1,200 cm., being thus more elongated than those recorded by Osborn and Mook for *Camarasaurus*. On the rounded anterior border each pubis attains a thickness of about 70 mm. The ischial or posterior border is very incomplete in both specimens, and there is no evidence of the acetabular surface.

There is no median thickening on the shaft, as in scapulæ, and the ischial border is much thinner than the anterior edge. When viewed lengthways the incomplete ischial border is slightly curved, and in the upper moiety

of the right pubis, as preserved, there is evidence of an extension which probably denotes a median symphysis, supplementing the distal. When viewed anteriorly there is no marked curvature on the shaft as a whole. A proximal fragment of the right pubis (?) is shown in Plate IV., fig. 2, but it cannot be placed into actual juxtaposition with the remainder.

The distal expansion is evenly convex. It attains an antero-posterior diameter of 300 mm. Here the lateral borders are somewhat less thick than the median region, which attains about 70 mm. in both specimens. There is evidence on the inner side of a rugose facet for the symphysis. In its distal contours the pubis of *Rhœtosaurus* is more evenly expanded than that of *Ornithopsis eucamerotus* as figured by Hulke[6]. In this region it more closely resembles the pubis of *Ornithopsis leedsi* (*Cetiosaurus*), as figured by Seeley, but our bone is more elongated[7].

In comparison with the massive fragments of the ilia the pubic and ischial remains seem slight.

Femur.—(Text figures 1-4). In my previous paper only two fragments from the shaft of the large femur were available, and these were described and illustrated. Most fortunately, Mr. A. J. Browne and I were able to find five additional sections from the same bone. These were not found in juxtaposition, but were scattered over the site of the fossil and were only discovered when yards of the superficial soil had been removed. These sections were heavily involved in matrix, and, in addition, a much abraded fragment of rib was crushed obliquely into the head of the bone. When freed from matrix it was obvious that these five sections formed with the two received in 1925 an almost complete right femur. As will be seen, the dimensions of this huge bone fully justify the forecast made from the sections of the femoral shaft in the first paper, when a length of over five feet was suggested.

The femur is a massive bone, the main contours of which are somewhat similar to that of *Camarasaurus* as described and figured by Osborn and Mook (*loc. cit*). The shaft is solid throughout, as is demonstrated by examination of the transverse sections exposed. The more central portions of the bone, however, are coarsely cancellous and in places almost spongy. The platey structure of the periphery of the shaft, when freed from matrix, showed a tendency to fracture into small elongated pieces until reinforced by adhesive solutions.

Unfortunately the distal end is still incomplete. There is a deep intercondylar groove, which gives evidence of large external and internal condyles. Judging from the broken curves these do not appear, however, to have been as massive and overhanging as in "*Atlantosaurus*" as figured by

[6] J. W. Hulke, Quart. Journ. Geol. Soc. XXXVIII, 1882, Plate XIV.

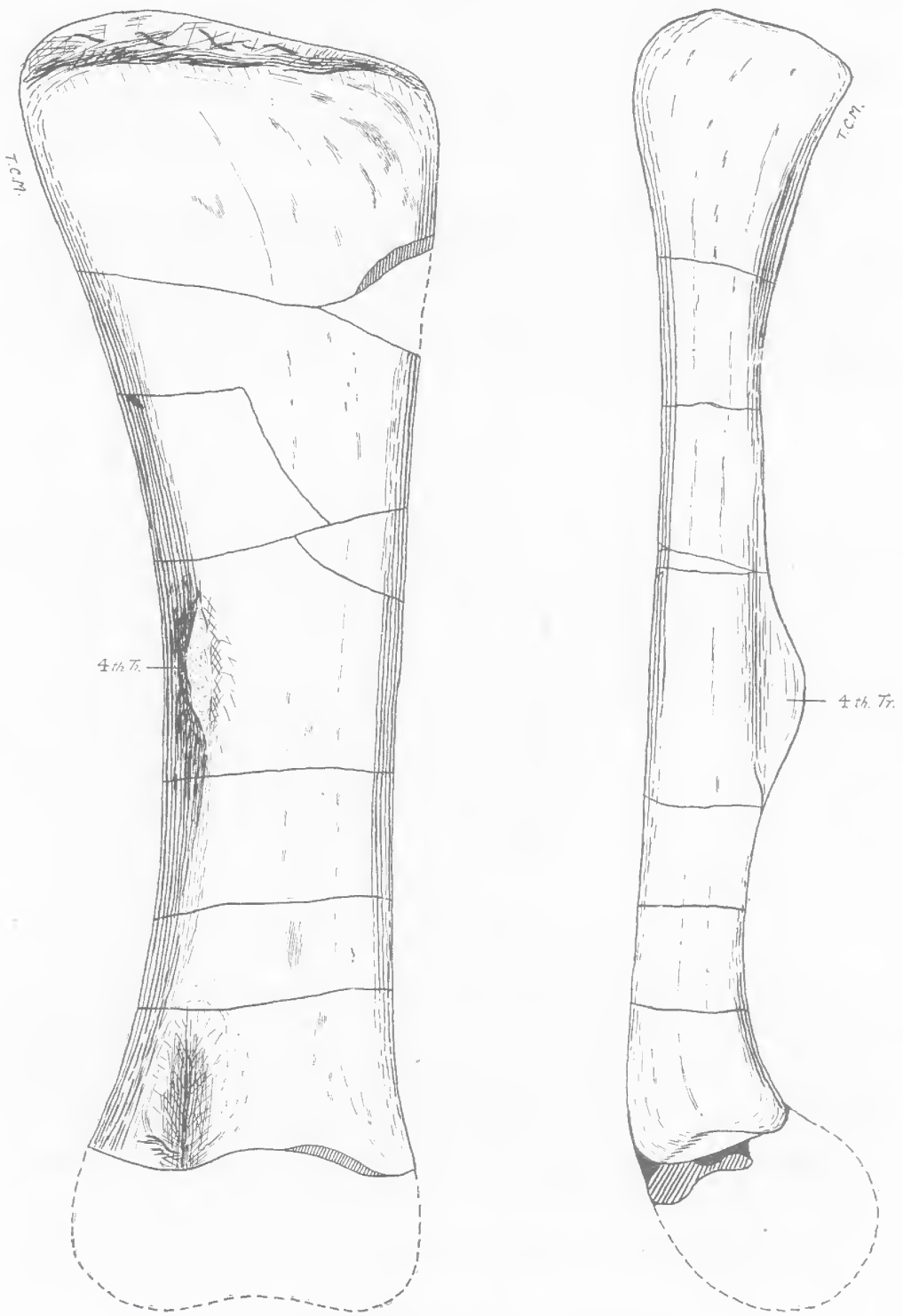
[7] H. G. Seeley, Quart. Journ. Geol. Soc., XLV., 1889, p. 392.

Fig. 1.

Fig. 2.

Fig. 1.—Left Pubis of *Rhætosaurus brownei*. (External view.)
Fig. 2.—Right Pubis of *Rhætosaurus brownei*.
(Two-ninths natural size.)

Face page 8.

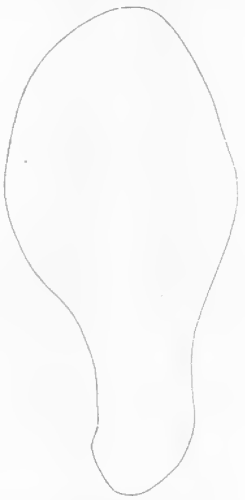


Text-fig. 1.—Femur of *Rhætosaurus brownei*.

Marsh, Plate XVI[8], but more closely resemble the distal ends of *Camarasaurus* and *Cetiosaurus*.

The actual length of the preserved portions, as placed in juxtaposition, is 137·6 cm., or just over four feet six inches. The distal portion has been tentatively reconstructed, as shown in the accompanying text-figures, making a total length of just over five feet.

The fourth trochanter is an elongated oval eminence about 150 mm. in length. The proximal and distal margins rise gradually from the shaft, but in transverse section (text-fig. 3) the eminence is much more abrupt. In this region the femur attains a maximum circumference of 79 cm., and the bone is surprisingly thick on its posterior border. The centre of the fourth trochanter is situated 76 cm. from the head of the bone, and in the reconstruction the eminence is central.



Text-fig. 2.

Text-fig. 3.

Text-fig. 4.

Femur of *Rhœtosaurus brownei*.

Text-figure 2.—Section through head.

Text-figure 3.—Section showing maximum contours in region of 4th trochanter.

Text-figure 4.—Section through distal end of preserved portion. (One-eighth natural size.)

In the fourth trochanter of *Cetiosaurus leedsi* as figured by A. Smith Woodward[9] the eminence is situated distinctly nearer to the head, but in *Camarasaurus* the position is almost identical with that in *Rhœtosaurus*.

With the exception of the actual summit, the contours of the eminence in *Rhœtosaurus* are very smooth.

[8] Marsh, The Dinosaurs of North America, 16th Ann. Rep. U.S. Geol. Survey, 1896.
[9] Smith Woodward, P.Z.S., 1905, p. 242.